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(54) LOAD INDICATOR FOR MOORING LINE

(71) We, GLOBAL MARINE INC., a corporation organised and existing under the laws of the State of Delaware, United States of America, of Global Marine House, 811, West Seventh Street, Los Angeles, California, United States of America, formerly of 650, South Grand Avenue, Los Angeles, California, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to mooring systems for vessels, and more particularly to apparatus and method for determining the load on a mooring line of a floating vessel.

The operator of a moored floating vessel is often concerned with whether the mooring lines of the vessel are overstressed. Breakage of a mooring line results in the loss of expensive anchors and mooring cable or chain. Obviously, the parting of a mooring line can also place the vessel itself in serious danger.

Attempts have been made in the past to give a ship operator an indication of the load on the vessel mooring lines. These attempts involved the use of strain gauges applied to the mooring line, say to a link of a mooring chain. The strain gauges monitored the elongation of the link under stress, the amount of stress sensed being useful to estimate mooring line load by reference to load/stress data for the chain being monitored.

A major shortcoming of strain gauges results from the fact that they must be applied to the particular chain link or portion of a wire cable that is adjacent the vessel outboard of a hawsepipe, chock or fairlead. Such gauges must be applied to the mooring line each time the line is paid out since it cannot be known in advance which chain link or portion of the cable will be located next-outboard of the vessel for that particular mooring. The fragility of strain gauges does not permit them to withstand readily the rough treatment to which they are subjected on a vessel. Also, it is time consuming and requires significant expertise to properly apply a strain gauge to a chain link or to a wire rope mooring line. For these reasons, strain gauges have not been widely or very successfully used to monitor and measure mooring line loads.

Mathematical relationships exist which describe the load in a catenary line for a particular geometry of the line. The present invention utilizes these relationships and the fact that a mooring line of a marine vessel can be treated as a catenary. A catenary is the shape assumed by a perfectly flexible line hanking between two support points. Although a mooring line, especially a mooring chain, generally is not a perfectly flexible line, it can be treated as such for the purpose of quite closely approximating loads developed in it.

The invention provides a method for ascertaining the tension in a mooring line extending from an anchor to a point of support on a vessel disposed in a body of water, the method comprising the steps of a) providing a graphical representation of the variation of tension in a mooring line having the same paid out length and physical characteristics the same as the mooring line of interest as functions of vertical distance between the point of support and the anchor and of a parameter the value of which varies in relation to the horizontal distance between the point of support and the anchor, b) measuring the aforesaid vertical distance and the value of said parameter, and c) locating on the graphical representation a unique point common to the measurements thereby to obtain a value of tension present in the mooring line of interest.

The invention also provides a method for ascertaining the tension in a mooring line extending from an anchor to a point of support on a vessel disposed in a body of water, the method comprising the steps of a) generating a signal the value of which is indicative of the value of the angle between the mooring line next adjacent the point of support outboard of the vessel and a horizontal reference plane, b) modulating the generated

signal in a predetermined manner by additional signals indicative of immersed weight per foot of the mooring line, vertical distance between the point of support and the anchor, and the amount of line paid out from the vessel between the point of support and the anchor, and c) applying the modulated signal to means for visually displaying the value thereof in terms of tension in the mooring line.

The invention also provides apparatus adapted for use in measuring the tensile load in a mooring line extending from an anchor to that point of line support on a moored vessel most outboard of the vessel along the line and comprising shoe means releasably engageable with the mooring line adjacent to and outboard of the point of support for assuming an attitude determined by the slope of the mooring line out-board of and next adjacent to the point of support, means for connecting the shoe means to the vessel to prevent movement of the shoe means along the mooring line away from the vessel, means co-operatively associated with the shoe means and responsive to a change in attitude of the shoe means by reason of a change in slope of the mooring line for manifesting the value of a selected parameter of the mooring line installation which parameter is correlative to the tension in the line.

A method and apparatus embodying the invention are described by way of example hereinafter with reference to the accompanying drawings. This method is for ascertaining the tension in a mooring line extending from an anchor engaged with the bottom of a body of water to the most outboard point of support, such as a chock, on a vessel floating on the body of water. The method comprises the step of providing a graphical representation of the variation of the tension present in the mooring line as functions of the relative vertical and horizontal positions of the chock and the anchor, and of the length of mooring line extending between the anchor and the point of support. The vertical distance between the chock and the anchor is measured, and the horizontal distance between the chock and the anchor is determined. These measurements are then applied to the graphical representation to locate a point thereon common to said measurements. The point indicates the load to which the mooring line is subjected. For a given depth of water and mooring line characteristic, the slope of the line at the vessel is a function of the length of line paid out and can be measured instead of the horizontal distance between the vessel and the anchor. Measured values of appropriate variables are used to locate a liquid point on the graph, thereby to obtain a value of mooring line tension.

The apparatus embodying the invention provides indicator means for indicating the slope of the mooring line relative to a horizontal reference plane at the point most outboard of the vessel at which the line is supported by the vessel. Means are provided for operatively connecting the indicator means to the mooring line. The mooring line indicator is constructed so that line can be taken in or paid out from the vessel without totally disconnecting the indicator means from the mooring line.

Thus the vessel operator is enabled to determine the load on his mooring line as well as on the anchor itself. Thus, he can be alerted if the anchor is in danger of being lifted off the ocean floor; in the past it was not possible for him to obtain such an objective indication, since strain gauges are incapable of measuring this phenomenon directly or indirectly. Formerly, the operator had to rely almost exclusively on his experience and intuition to determine when the anchor might be lifted off the ocean floor.

There now follows a description to be read with reference to the accompanying drawings, of various embodiments of the invention. This description which is illustrative of both method and apparatus aspects of the invention is given by way of example only and not by way of limitation of the invention.

In the accompanying drawings:—

Fig. 1 is a view of a moored vessel, the parameters pertinent to catenary analysis, from which this invention proceeds, being shown relative to the vessel mooring system;

Fig. 2 is a fragmentary side elevational view, partially in section, of a vessel fitted with apparatus for indicating the slope of the mooring line;

Fig. 3 is a graphic representation of mooring line tension as a function of the water depth and the angle between the mooring line and the horizontal;

Figure 4 is similar to Figure 2 and shows another embodiment of apparatus of this invention;

Figure 5 is a graphic representation of the relation of chain angle below the horizontal to chock height above the waterline and to the number of chain links between the chock and the waterline;

Figure 6 is a graphic representation of the relation of mooring line tension to water depth and to the vessel's horizontal displacement from its anchor;

Figure 7 is a fragmentary elevation view of another embodiment of the invention; and

Figure 8 is a block diagram of an instrumented automatic measurement system embodying this invention.

The forces at work in a mooring line susceptible of forming a catenary curve (a perfectly flexible mooring line such as is approximated quite closely by a braided wire rope or by a marine anchor chain) may be analysed from a consideration of "Mathe-

matics of Physics and Modern Engineering", Sokolnikoff and Redheffer, McGraw-Hill, New York, 1958 pages 40—42 and "Higher Mathematics for Engineers and Physicists", Sokolnikoff and Sokolnikoff, McGraw-Hill, New York, 1941, pages 245—252. Such an analysis would of itself approach the catenary aspect of mooring line systems from a theoretical point of view, and the data would require multiple entries to extensive tabular data and extensive computation to obtain solutions for specific problems. This invention provides procedure and apparatus which enable the personnel involved on a particular floating vessel, equipped with mooring line of known physical properties and dimensions, to determine rapidly, accurately and without computation or mental evaluation and decision the mooring line tension (the parameter of the mooring system most generally of interest) by reference either to graphs prepared especially for use with the line on board or to an indicator mechanism coupled to the line.

The following description is presented with reference to chain mooring line. Users of wire rope mooring lines will be able to practice this invention in view of the following discussion considered in the light of the above cited reference works, and thus the broad aspects of this invention comprehend both chain and wire rope mooring systems.

Fig. 1 shows the parameters and variables at play in a catenary mooring system connected between a floating vessel 12 and an anchor 14. The nomenclature used in Fig. 1 is the same as is used in the above-cited Collipp et al work, such similarity of nomenclature being adopted for the convenience of workers in the art to which this invention pertains desiring to practice this invention in respect to mooring systems different from this discussed herein.

As shown in Fig. 1, a mooring line 10 is connected to vessel 12 floating on the surface 13 of a body of water 15, via a hawsepipe 17 through which the line is led to a suitable winch. The total length of line paid out by the vessel from the hawsepipe (or fair-lead or closed chock, if applicable, depending on the type of mooring rigging selected) is indicated by parameter S. The vertical distance from the hawsepipe, the most outboard point of support of the mooring line by the vessel, to anchor 14 is indicated by parameter h, h being the sum of water depth D and the height d of the hawsepipe above the vessel's draft waterline. Parameter L is the distance horizontally from the hawsepipe to the anchor. The load in the line at the anchor, or at the point along the line at which the line begins to lie along the ocean bottom in instances where the anchor is not the lower terminus of the catenary portion of the length of the line, is force R_o which has vertical and horizontal components R_V and R_H. The tension load in the mooring line at the vessel, this being the load value most commonly of interest, is T_o and has vertical and horizontal components T_V and T_H.

For any available mooring line, be it chain or woven wire rope, the weight of the line per foot of length in sea water can be determined readily; this characteristic of the line is referred to herein as parameter w. Also, in any given mooring situation the operator of the vessel knows, or has ready means to determine, the length S of line paid out. Parameter h can be determined readily for any given vessel and mooring situation since water depth D is known either from mariners' charts or from depth soundings, and distance d is a physical property of the vessel. With w, S, and h being known, only θ, the angle of declination of the mooring line at hawsepipe 17 from a horizontal reference line, need be known to enable a mathematical determination of the value of T_o. This is true because between the hawsepipe and the anchor, or point at which the mooring line begins to lie along the ocean bottom, the mooring line assumes a predictable catenary path determined by w, S, h.

However, because for a given vessel equipped with specified mooring line the values of d and w are known, only θ, S and D additionally need be known to enable a determination of T_o. Also, since in a given mooring situation S and D are known, only θ really need be determined. θ, in turn, is a measure of the effective length of mooring line capable of catenary action for a given type of mooring line used in connection with a given value of h. These facts, then, enable the use of graphs to determine T_o once θ has been determined. Alternatively, θ need not be known to enable a graphical solution for T_o if L is known. Frequently L is known where the anchor is a pile or the like projecting above the water surface or can be determined by the use of shipboard acoustical depth sounders; where depth sounders are used to determine L, the use of an acoustic reflector on the anchor may be in order.

Fig. 3 is a graph 21 useful in determining mooring chain tension at a hawsepipe or closed chock when θ and h are known for a given size of chain; the graph of Fig. 3 pertains to a 15/16 steel anchor chain. As shown in Fig. 3, values of T_o are plotted vertically on Cartesian co-ordinates and values of θ are plotted horizontally. Contours 16 and 20 for varying values of h are also presented on the graph. Thus, knowing h and θ, it is essentially a mechanical, rather than a mathematical or reasoning process to determine T_o. For example, if the vertical distance $h=D+d$ from the ocean flooor to the most outboard point of support of the chain by the vessel $(D+d)$ is 60 feet (curve 16) and

the angle of declination (θ) of the chain from a horizontal reference plane at the point of support is 17.5°, the tension in the 15/16 inch chain at the point of support is approximately 13,000 pounds as given by point 18 on curve 16. (T_o normally is the maximum tension present in the chain between the vessel and the anchor.) Similarly, if the value of h is 100 feet, curve 20 is used to determine the maximum value of chain tensile load. In using graph 21 S, the amount of chain paid out, is at least 5h which is the case with most mooring situations.

In practice, graph 21 includes a plurality of contours similar to curves 16 and 20, each contour corresponding to a different value of h.

It will be understood that a different graph, each similar to graph 21, is required for each different size of chain or cable which may be used on a particular vessel. Each different graph reflects a particular value of w.

Figure 6 shows a graph 22 which may be used to determine the value of T_o for a particular mooring line in instances where L, the horizontal distance from the anchor to the nearest point of support of the mooring line by the vessel, is known; graph 22 does not involve knowledge of the value of θ. A graph 22 is prepared for each size of chain or mooring cable which may be used. As in graph 21, the vertical ordinate in graph 22 is the mooring line tension T_o ordinate. Horizontal distance L is plotted horizontally in graph 22. A family of contours 23, each corresponding to a particular value of h, also is plotted in the graph.

Referring now to Fig. 2, a sensing indicator 25 for determining the angle of declination from the horizontal of anchor chain 26 is shown. Chain 26 extends from a winch 27 through a closed chock 28 from vessel 12 to the anchor; it will be understood, however, that indicator 25 may be used in conjunction with a hawsepipe or cable fairlead instead of with a closed chock, if desired. The last link of the chain engaged with the vessel is designated link 29. Engaged with the chain adjacent chock 28, outboard of the vessel, and above water surface 13 is a generally U-shaped elongated shoe 31 which is inverted and extends over a plurality of chain links. The engagement of the shoe with the chain is such that the length of the shoe assumes an inclination equal to the slope of the chain adjacent the vessel. The side legs of the shoe extend sufficiently downwardly of opposite sides of the chain to assure that the shoe does not separate from the chain in use of indicator 25. A support bracket 32 is mounted on shoe 31 and pivotally mounts an elongated radius arm 33 to the bracket by means of a bolt 34. A second support bracket 36 is secured to chock 28 and pivotally mounts a connector plate 37 which is pinned to the end of the radius arm 33 opposite from shoe 31. Preferably, the connector plate 37 is pivotal both about a horizontal axis defined by pivot pin 38 which mounts the plate to bracket 36 and about a vertical axis relative to the chock, defined by a hinge pin 39 which connects bracket 36 to the chock, such that shoe 31 and the radius arm can move with chain 26 relative to the vessel as the vessel moves in response to wind and wave action.

Suitable means, such as a nylon rope 40, is secured to the radius arm and the elongated shoe and is wrapped around the shoe and the chain in a direction transverse to the axis of the chain so that the shoe and the arm are secured to the chain. Preferably, the nylon rope is laced through eye-bolts 41 secured to the radius arm and to the shoe to facilitate the removal and attachment of the rope from the elongated shoe and the anchor chain. The anchor chain can be hauled aboard the vessel or additional chain can be paid out without having to remove the shoe since the chain slides freely in the space defined by the shoe and the rope. Also, the shoe is readily removable from the chain in the event that the anchor is weighed.

A scale 43, graduated in degrees of arc, is secured to bracket 36 and co-operates with a pointer 44 which is secured to plate 37 and extends radially from pivot pin 38. The pointer and the scale co-operate to define an indicator the scale 43 of which is oriented relative to the structure of the vessel so that the reading provided by the indicator is the angle between the chain outboard of the chock and a horizontal reference plane. Thus, indicator 25 provides a direct measurement of the value of angle θ, see Fig. 1. Once the slope of chain 26 outboard of the chock is known, the depth of the water below the vessel and the height of the chock above waterline 13 having been determined, the person desiring to know the tension in the chain consults a graphic diagram of the type shown in Fig. 3 to obtain directly therefrom the tension which exists in the chain.

To enable the reading of scale 43 even if the vessel pitches, as in a severe storm, the scale can be rotatably mounted on pin 38 and counterbalanced so that it always seeks what corresponds to a horizontal position. This modification avoids the necessity of having to approximate the chain angle by averaging the different values of θ obtained at different times during motion of the vessel.

The use of graphs 21 may be avoided by the use in indicator 25 of a scale of the type shown in Fig. 7, especially where the depth D of water in which the vessel is floating is known. Fig. 7 shows an indicator 45 which is similar to indicator 25 except that instead of carrying a scale calibrated in degrees of arc, support bracket 36 carries a

removable scale card 46, preferably made of plastics or celluloid to be resistant to the effects of weather, which incorporates the data of graph 21 for a selected range of values of D; lines 47 and 48 do not correspond to values of h since, for a given vessel, d is known, although lines 47 and 48 could be representative of selected values of h, if desired. For example, as shown, card 46 includes inner and outer arcuate reference lines 47 and 48 concentric to pivot pin 38, which lines correspond to water depths of 60 and 100 feet, respectively. Curved lines 49 extend generally radially of the card between depth reference lines 47 and 48, such lines being constant tension value lines. One edge 50 of pointer 44 extends radially of pin 38 and is the edge of the pointer along which the card is read. An interpolating scale 51 is defined along pointer edge 50 so that water depths between 60 and 100 feet may be located readily. Similarly, a plurality of depth interpolating lines 52 are provided on the face of the card betwen lines 47 and 48. A set of scale cards 46, each covering a selected range of water depths, is provided for each size of chain which may be used. A given scale card is held in place on support bracket 36 by spring clips 53 engaged with the card at spaced locations around the common periphery of the card and the support bracket.

One desiring to determine the tension in chain 22 may use indicator 45 to obtain a figure of chain load directly. Knowing the depth of water in which the vessel floats, say 80 feet, such person merely reads along scale 51 to locate the appropriate depth and interpolates betwen adjacent constant tension value lines 49 along pointer edge 50 to determine the chain tension, about 18,500 pounds, for that position of the pointer. The pointer is coupled to the chain outboard of the vessel as described above regarding apparatus 25.

Although the embodiments of the invention shown in Fig. 1 and 7 work entirely satisfactorily and are an improvement over what has been available heretofore, it is frequently convenient to transmit measurements of the slope of the mooring line (Fig. 1) or of chain tension (Fig. 7) to a point removed from the mooring line itself. For example, the master of the vessel might wish to obtain information relating to the load on the anchor chain at the bridge of a ship. To transmit the readings of indicator 25 or 45 to a location remote from chock 28, an inclinometer 60 (Fig. 2) is secured to shoe 31. The inclinometer may be of conventional design readily available on the market. A suitable inclinometer is a potentiometer-type instrument manufactured by the Edcliff Instrument Company of Monrovia, California, Edcliff catalogue item number 5-510. The inclinometer measures the angle of inclination of the elongated shoe, and the mooring line, relative to a horizontal reference plane and generates electric signals indicative of the measured angle. Leads 61 transmit the generated signals to a remote place, say the bridge of the ship, where they are applied to an amplifier 62 and fed to a readout device 63, such as a strip chart recorder, calibrated to indicate either the slope of the mooring line or, by using a scale calibrated directly in terms of mooring line tension, the tension in the mooring line. The electric signals from the inclinometer may be modified in a computer 64 to correct the signals for any inaccuracies in the output of the inclinometer caused by pitching, rolling or heaving of the vessel. Information concerning water depth may be applied to the inclinometer output signal in the computer, if desired.

Fig. 8 depicts an automated system 80 for obtaining measurements of mooring line tension directly. In such system, the measurement of absolute line declination angle is applied from inclinometer 60 directly to computer 64 which contains a logic network for modulating the output of the angle sensing inclinometer to generate a line tension signal in a manner determined by the logic network and by the output of associated support signal generators. The support signal generators include an adjustable line constant signal generator 81, the output of which has a value indicative of the value of w for the mooring line then being monitored for tensions. Another adjustable signal generator 82 has an output which is indicative of the value of h for the particular mooring system. A third adjustable support signal generator 83 has an output which is indicative of the amount of mooring line paid out. The output of the computer is applied to a strip chart recorder 84 which uses record material 85 graduated in units of mooring line tension. The trace 86 produced by the recorder may be read to obtain a value of line tension.

In a simplified embodiment of this invention, a dial plate 65, shown in Fig. 4, is secured to the hull of vessel 12 in a vertical position adjacent chock 28. The dial plate carries a scale 66 calibrated in degrees of arc. By means of the scale, the inclination of the mooring line relative to a horizontal reference plane is determinable. To assist in reading the scale, a reference shoe 67, having a straight upper surface 68, is fitted to the chain adjacent plate 65 so as to be operatively coupled to the dial plate. If desired, scale 66 may be calibrated in terms of chain tension; in such instance the scale may be used only with a specified size of chain on a vessel moored in a known depth of water. Due to the large size of oceangoing vessels, and the difficulty with which a person may read a scale secured to the hull of such a vessel in the manner described immediately above, this embodiment of the invention is

best suited for use on smaller vessels such as river boats, barges, or the like.

This invention is further practiced without the need for any apparatus by simply counting the chain links between the chock of the vessel and the waterline. Since the height of the chock above the waterline is known or can be measured, and since the length of each link is known, the slope of the anchor chain can be determined without the need of scales to measure it. In this instance, it is most convenient to provide graphs 70 (see Fig. 5) in which the co-ordinate axes represent the chock height and the chain angle, respectively, and in which there are plotted curves 71 representing the number of chain links counted. A person can determine the chain angle from the number of links and the chock height. This angle is then used, by reference to an appropriate graph 21, for example, to determine the tension in the anchor chain.

It will be apparent from the foregoing that we believe that this invention provides efficient method and apparatus for rapidly and effectively determining the load present in a marine mooring line at a floating vessel.

WHAT WE CLAIM IS:—

1. A method for ascertaining the tension in a mooring line extending from an anchor to a point of support on a vessel disposed in a body of water, the method comprising the steps of a) providing a graphical representation of the variation of tension in a mooring line having the same pair out length and physical characteristics the same as the mooring line of interest as functions of vertical distance between the point of support and the anchor of a parameter the value of which varies in relation to the horizontal distance between the point of support and the anchor, b) measuring the aforesaid vertical distance and the value of said parameter, and c) locating on the graphical representation a unique point common to the measurements thereby to obtain a value of tension present in the mooring line of interest.

2. A method according to claim 1 wherein the parameter is itself the horizontal distance from the point of support to the anchor.

3. A method according to claim 1 wherein the parameter is the angle of declination of the mooring line at the point of support from a horizontal reference line.

4. A method according to claim 3 wherein the value of the parameter is measured directly.

5. A method according to claim 3 wherein the vessel floats on the surface of the body of water and the point of support is located above the water surface, and the measurement of the value of the parameter is obtained by a) providing a graphical representation of the value of said angle as functions of the height of the point of support above the water surface and of the length of mooring line exposed between the water surface and said point, b) measuring said height and said exposed length, and c) locating on the last-mentioned graphical representation a unique point common to the last-mentioned measurements to obtain a value of said angle.

6. A method according to claim 5 wherein the mooring line is defined by a length of chain, and in said graphical representation the length of mooring line exposed is in terms of the number of links of the chain exposed between the water surface and said point of support, and said measurement of exposed length is carried out by counting the number of chain links exposed between the point of support and the water surface.

7. A method according to any one of the preceding claims wherein the amount of mooring line paid out between the point of support and the anchor is at least five times greater than said vertical distance.

8. A method for ascertain the tension in a mooring line extending from an anchor to a point of support on a vessel disposed in a body of water, the method comprising the steps of a) generating a signal the value of which is indicative of the value of the angle between the mooring line next adjacent the point of support outboard of the vessel and a horizontal reference plane, b) modulating the generated signal in a predetermined manner by additional signals indicative of immersed weight per foot of the mooring line, vertical distance between the point of support and the anchor, and the amount of line paid out from the vessel between the point of support and the anchor, and c) applying the modulated signal to means for visually displaying the value thereof in terms of tension in the mooring line.

9. Apparatus adapted for use in measuring the tensile load in a mooring line extending from an anchor to that point of line support on a moored vessel most outboard of the vessel along the line and comprising shoe means releasably engageable with the mooring line adjacent to and outboard of the point of support for assuming an attitude determined by the slope of the mooring line outboard of and next adjacent to the point of support, means for connecting the shoe means to the vessel to prevent movement of the shoe means along the mooring line away from the vessel, means co-operatively associated with the shoe means and responsive to a chain in attitude of the shoe means by reason of a change in slope of the mooring line for manifesting the value of a selected parameter of the mooring line installation which parameter is correlative to the tension in the line.

10. Apparatus according to claim 9 wherein the selected parameter of the mooring line installation is the slope of the line next

adjacent to and outboard of said point of support.

11. Apparatus according to claim 9 or claim 10 comprising means operatively coupled to the shoe means responsive to attitude changing movement of the shoe means for visually indicating the angle of the mooring line at the shoe means to a horizontal reference plane.

12. Apparatus according to claim 11 wherein the operatively coupled means comprises an inclinometer mounted to the shoe means for generating a signal indicative of the value of said angle, and means remote from the shoe means to which said signal is applied for visually indicating the value of said angle.

13. Apparatus according to claim 11 wherein the operatively coupled means comprises an inclinometer mounted to the shoe means for generating a signal indicative of the value of said angle, and means remote from the shoe means to which said signal is applied for visually indicating the value of tension present in a mooring line with which the shoe means is engaged.

14. Apparatus according to any one of claims 9 to 13 wherein the means co-operatively associated with the shoe means comprises a dial member mounted to the vessel adjacent the point of support, a dial pointer mounted to the dial member for movement relative thereto, and means associating the shoe means with the dial member and the pointer and arranged so that the pointer moves relative to the dial member in response to changes in attitude of the shoe means.

15. Apparatus according to claim 14 wherein a scale card is received by the dial member in a selected position thereon relative to the pointer, the scale card being calibrated to indicate the tension in a particular mooring line with which the shoe means is engageable.

16. Apparatus according to claim 15 wherein the scale card defines a graphical representation of the relation, for a given mooring line of characteristic immersed weight per foot and physical type, between

a) mooring line slope at the shoe means,

b) the vertical distance between the point of support and the anchor, and

c) the tension in the given line at said point of support, the representation being displayed upon co-ordinate axes in which, when the card is received on the dial member in said selected position, varying values of said vertical distance are scaled along an axis parallel to the pointer, varying values of mooring line slope are scaled along an axis extending in the direction of movement of the pointer relative to the dial number, and varying values of tension are presented as contours relative to said co-ordinate axes.

17. Apparatus according to any one of claims 14 to 16 wherein the dial pointer is rotatable relative to the dial member, and the pointer has an edge thereof which extends radially of its axis of rotation relative to the dial member.

18. Apparatus according to any one of claims 14 to 17 wherein the dial is movably mounted to the vessel, and comprising balance means coupled to the dial for maintaining the dial in a predetermined relation to a horizontal reference plane irrespective of the attitude of the vessel.

19. Apparatus according to claim 9 comprising a graphical representation, prepared for a given mooring line of characteristic type and having characteristic immersed weight per foot, of the variation in mooring line tension as functions of vertical distance between the point of support and the anchor and of the slope of the mooring line at the shoe means.

20. Apparatus according to any one of claims 9 to 19 wherein the shoe means is constructed to allow the mooring line to be paid out from or taken aboard the vessel without requiring removal of the shoe means from the mooring line.

21. A method for ascertaining the tension in a mooring line substantially as hereinbefore described with reference to Figure 1 and Figure 2, Figure 4 or Figure 7 of the accompanying drawings.

22. A method for ascertaining the tension in a mooring line substantially as hereinbefore described with reference to Figure 1 and Figure 3 or Figure 6 of the accompanying drawings.

23. A method for ascertaining the tension in a mooring line substantially as hereinbefore described with reference to Figure 5 of the accompanying drawings.

24. A method for acertaining the tension in a mooring line substantially as hereinbefore described with reference to Figures 1, 2 and 8 of the accompanying drawings.

25. Apparatus adapted for use in measuring the tensile load in a mooring line, constructed, arranged and adapted to operate substantially as hereinbefore described with reference to Figure 1 and Figure 2, Figure 4, or Figure 7 of the accompanying drawings.

26. Apparatus adapted for use in measuring the tensile load in a mooring line, constructed arranged and adapted to operate substantially as hereinbefore described with reference to Figures 1, 2 and 8 of the accompanying drawings.

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1241776 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

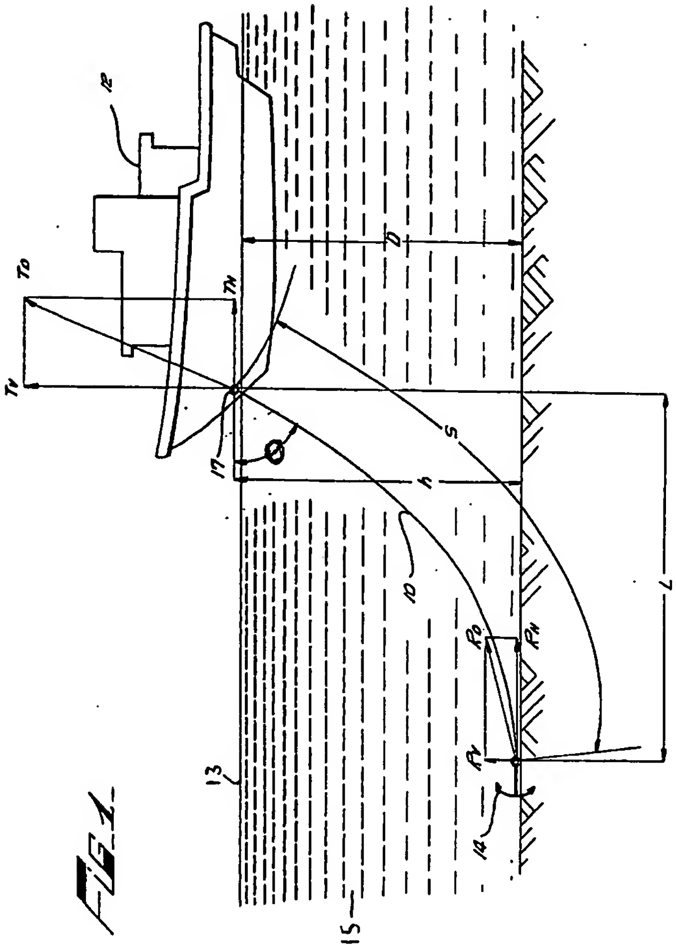


FIG. 1

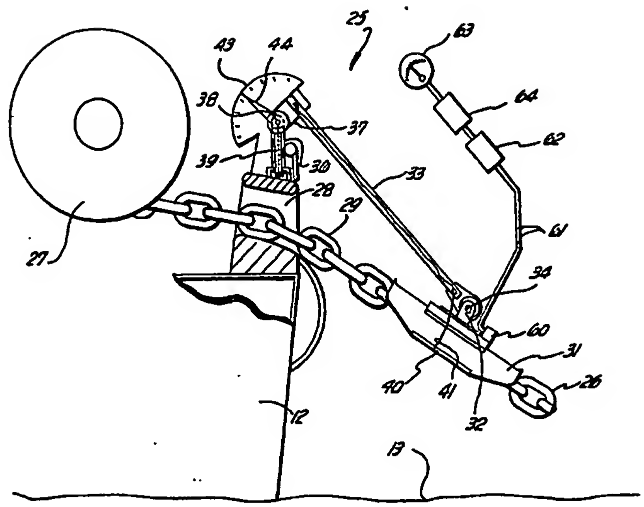
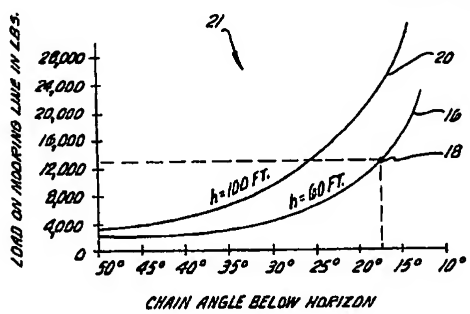

25
63
43
44
38
64
37
62
39
30
33
28
29
61
27
34
60
31
26
40
41
32
12
13

FIG. 2

FIG. 3


21
LOAD ON MOORING LINE IN LBS.
28,000
24,000
20,000
16,000
12,000
8,000
4,000
0
20
16
18
h=100 FT.
h=60 FT.
50° 45° 40° 35° 30° 25° 20° 15° 10°
CHAIN ANGLE BELOW HORIZON

1241776 COMPLETE SPECIFICATION

4 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 3

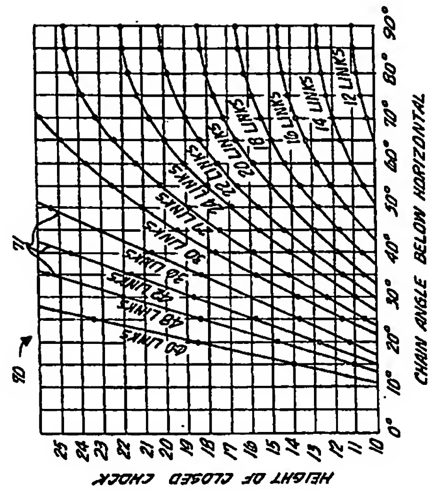


FIG. 5

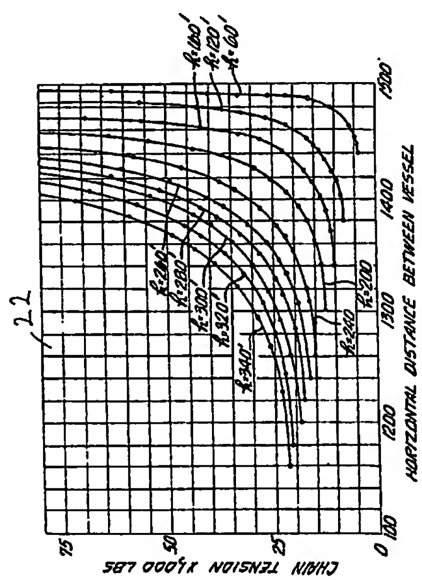


FIG. 6

1241776 COMPLETE SPECIFICATION

4 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 4

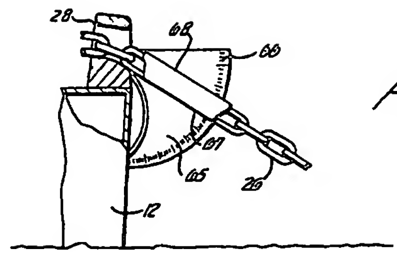


FIG. 4.

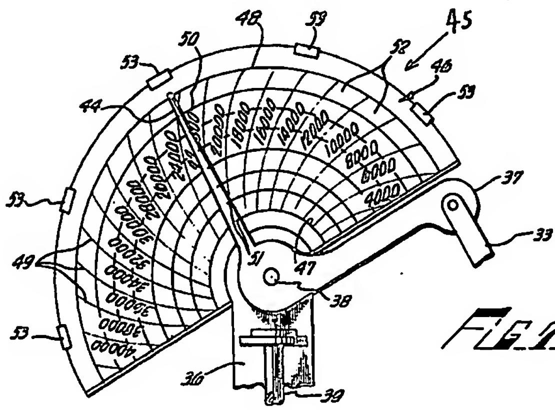


FIG. 7.

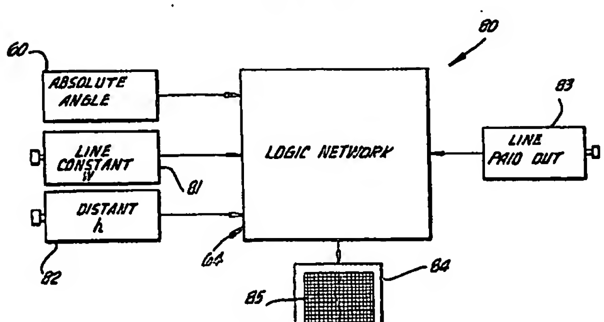


FIG. 8.